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Tokuhide Shimojo received a B.S. degree in Physics from the Osaka City University. He then joined the Fujitsu Laboratory in Kobe where he investigated electroluminescence of ZnS, solid state image intensifiers, crystal growth of PbO, and semiconductor surfaces by mean of Low Energy Electron Diffraction and Auger Electron Spectroscopy in turn. He joined Ise Electronics Corp. in 1971. Since coming to Ise Electronics Corp, he has been working on Liquid Crystals and the other display devices. He is a member of the Physical Society of Japan and the Japan Society of Applied Physics.

FIELD-EFFECT LIQUID CRYSTAL DISPLAYS WITH INTERDIGITAL ELECTRODES

by

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ABSTRACT

Field effect liquid crystal displays using nematic liquid crystals of negative dielectric anisotropy are presented, where a new electrode configuration is adopted. Threshold voltage, contrast, viewing angle and color variations due to the applied voltage of the cell are described. Display characteristics are discussed and a digital clock device utilizing the cell is demonstrated.

INTRODUCTION

There are three modes of liquid crystal displays which have been applied to numerical or matrix displays.

The first one is the dynamic scattering mode (DSM) which was proposed by G.H. Heilmeier et al[1] and has been applied to displays from the first time. Though DSM has been developed and improved, there are some disadvantages due to the nature of this mode, e.g., it needs ionic current. The other two modes utilize purely dielectric effects in contrast to the conduction effect of DSM.

The second mode uses the electro-optical effect of twisted nematic (TN) liquid crystals reported by Schadt et al[2]. This mode has advantages of low threshold voltage,[3,4] multicolor[5] and low power consumption[5,6]. Now some devices using TN cells are available, however, a serious disadvantage of the TN cell is higher cost coming from manufacturing difficulties.

The third mode is electrically controlled birefringence (ECB) or deformation of vertically aligned phase (DAP). It also belongs to the field effect type. Multicolor matrix displays have been developed by using DAP liquid crystal cells[7,8]. Though these liquid crystal cells have the advantages of low power consumption, low threshold voltage and multicolor ability compared with DSM, there are some disadvantages described below:

1. The viewing angle is narrow[8,9]
2. The color is sensitive to the applied voltage and the thickness of liquid crystal layer. Therefore it is difficult to make a large uniform DAP cell. These

disadvantages have been considerably overcome by adopting crossed interdigital sandwich electrodes. Some electro-optical characteristics of this type of cell are presented, and a digital clock display using this effect is demonstrated.

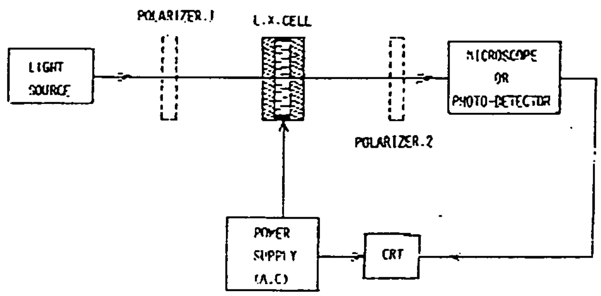

Figure 1 – Schematic diagram of experimental arrangement.

PREPARATION OF THE LIQUID CRYSTAL CELL

The experimental arrangement is shown in Fig. 1. White light emitted from the light source is passed through polarizer, 1, the L.X. cell, and polarizer 2, and is detected by a photodetector attached to a microscope. Linear or elliptical polarizers are used. The cell is activated by zero-centered sine and square waves (300 Hz – 10 kHz).

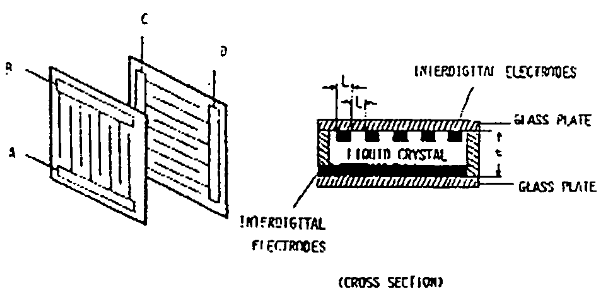

Figure 2 – Electrode configuration of the experimental cell. A, B, C, and D indicate lead-wire for connection. t is the thickness of L.X. layer.

The experimental cell is constructed with two glass plates having transparent interdigital electrodes made of indium-oxide as shown in Fig. 2. The width of interdigital electrodes (L) which is also the distance between electrodes is varied from 20 um to 100 um. The gap of the cell (t) is varied from 10 um to 30 um. Electric power is applied to the cell through two types of connection, X and Y, as shown in Fig. 3. X-connection is practical and Y-connection is rather special. The states of birefringence have been observed in both cases. Liquid crystals used in this study are azoxy-benzene and Schiff base compounds which are aligned vertically between the plates. These materials show negative dielectric anisotropy. The glass surfaces in contact with the liquid crystal are occasionally coated with some material in order to aid vertical alignment of molecules. Fig. 4 shows a comparison of the electrode geometry between the new and conventional liquid crystal cells.

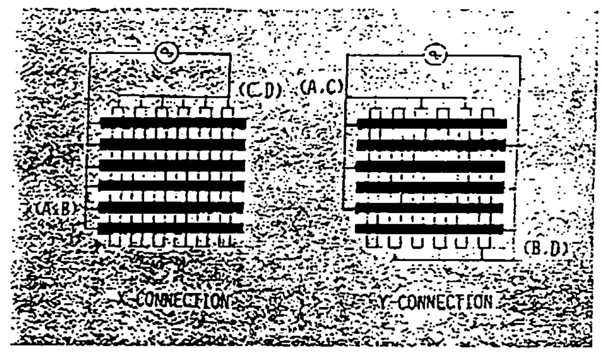

Figure 3 – Two types of electrode connections for the application of voltage.

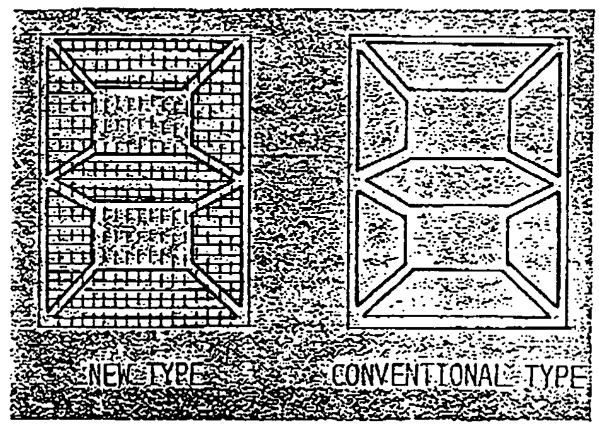

Figure 4 – Comparison of the electrode geometry between the new and conventional L.X. cells.

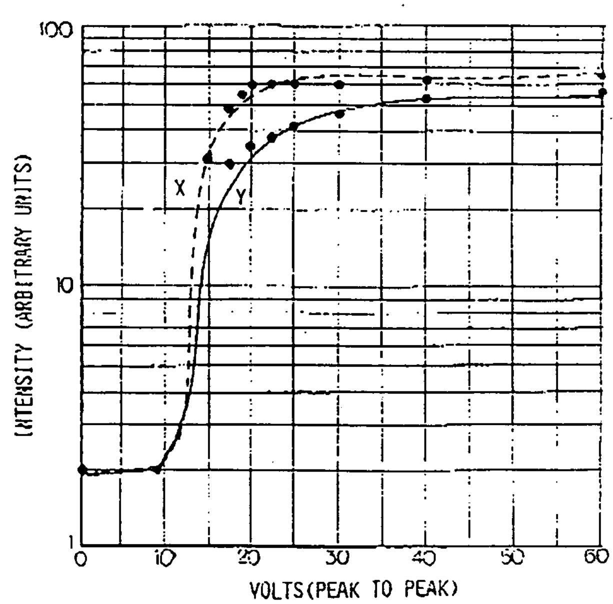

Figure 5 – Transmitted light intensity VS. applied voltage (10 KHz). Solid line: Y-connection, dashed line: X-connection.

ELECTRO-OPTICAL CHARACTERISTICS

Transmitted light intensity vs applied voltage is shown in Fig. 5. In this cell, L and t are 20 um and 10 um, respectively. The direction of incident light and photodetector is perpendicular to the cell. The figure indicates that threshold voltage is about 12 Vp-p in both connections. In this case, the applied power is a 10 KHz square wave. The angular distribution of the transmitted light intensity of the same cell has been measured. As shown in Fig. 6, these characteristics assure wide viewing angle in both connections. This wide viewing angle is one of advantages of the new liquid crystal cell. The response time measured is nearly the same as the usual DSM liquid crystal. These characteristics are independent of the frequency if it is higher than the cut off frequency which was measured to be 300 Hz in this experiment. The tendencies of these characteristics are the same throughout the experiment, but the threshold voltage and response time change according to the cell dimension.

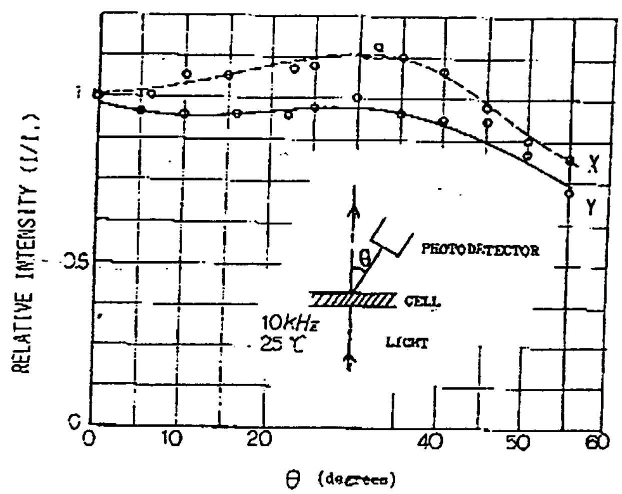

Figure 6 — Angular dependence of the transmitted light intensity. Solid line: Y-connection, 40 Vp-p. Dashed line X-connection, 30 Vp-p.

The displayed color of a DAP cell is generally known to be very sensitive to the applied voltage and thickness of the liquid crystal layer. This is one of disadvantages of DAP liquid crystal displays. In the present cell with crossed interdigital electrodes, the problem is greatly diminished. The pattern of birefringence observed by a microscope is shown in Fig. 7 and Fig. 8, the former represents the X connection and the latter, the Y connection. A, B, and C indicate different voltages applied to the cell and the applied voltage is a 10 KHz square wave in both cases. There are many small bright patches and fine lines in both figures, which actually show different colors (blue, green, red, yellow, etc.) distributed regularly among these patches

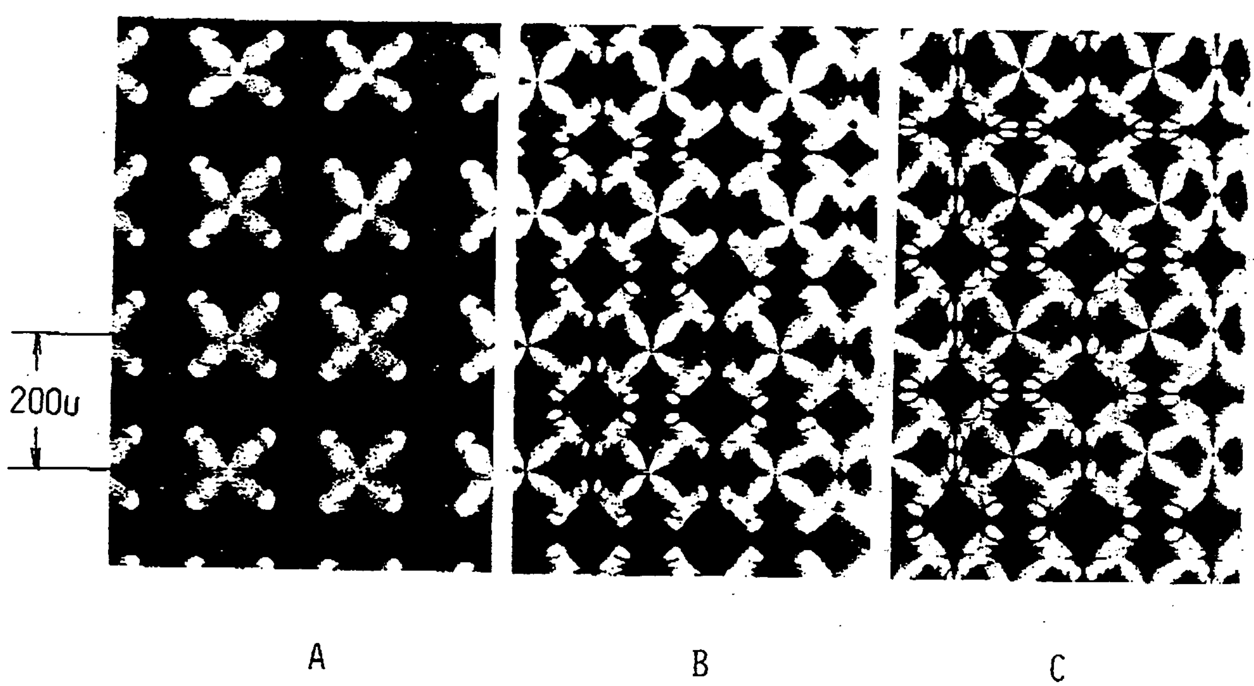

Figure 7 — Pattern of birefringence observed by a microscope for X-connection. L=100 um, t=30 um A; 20 Vp-p (threshold), B; 30 Vp-p, C; 40 Vp-p. (10 KHz square wave)

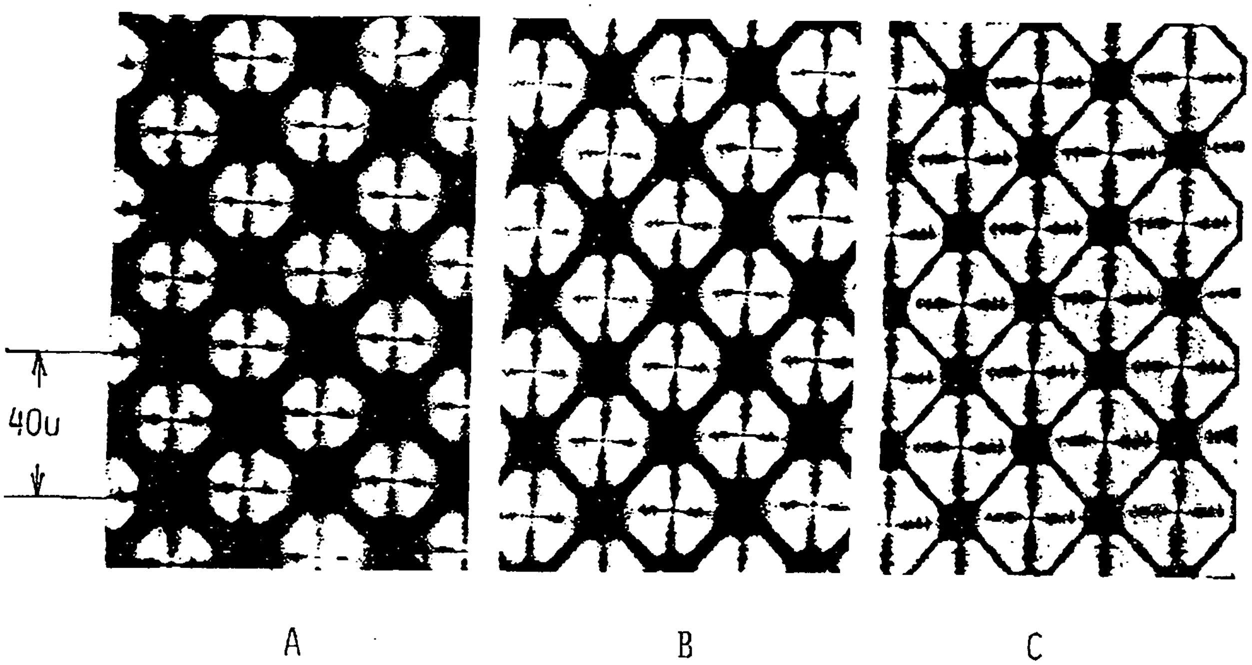

Figure 8 — Pattern of birefringence observed by a microscope for Y-connection. L=20 um, t=10 um, A: 13 Vp-p (threshold), B; 20 Vp-p, C; 30 Vp-p.(10 KHz square wave)

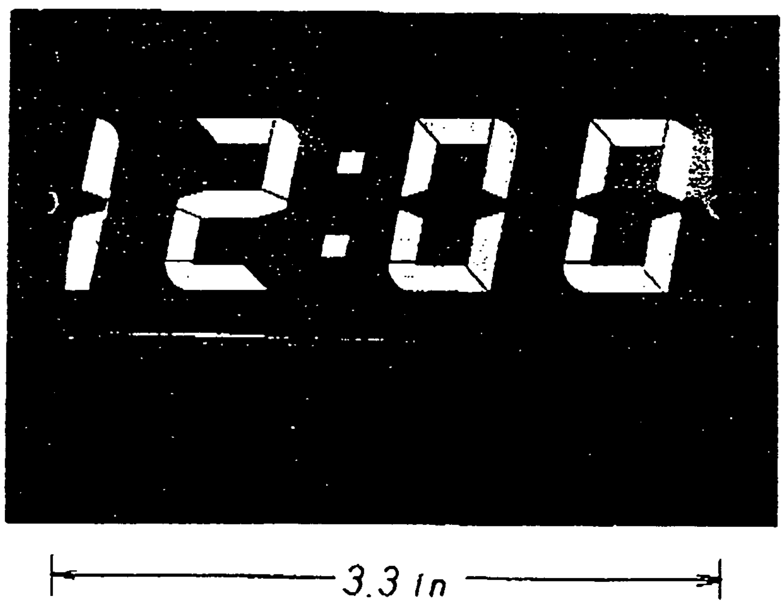

Figure 9 — Digital clock device using new interdigital electrodes. 30 Vp-p, 300 Hz. X-connection.

and lines. Both the light pattern and color are sensitive to the applied voltage on a microscopic scale, but the general color impression as a whole is not so sensitive to the applied voltage, e.g., the observed color depends mainly on the body color of the polarizer. The microscopic color change with applied voltage depends on the dimensions of the cell but not the applied frequency. If "t" is fixed to 20 um, L has to be smaller than 60 um in order to minimize the macroscopic color changes. It is also observed that the macroscopic color changes are larger in the X-connection than in the Y-connection. Wide electrode strips are desirable for the convenience of cell construction, but L has to be smaller than 3t for the purpose of small macroscopic color change. On the other hand, small t is desirable in order to get wide viewing angle and low threshold voltage. As a practical compromise, the maximum L value may be 100 um.

The digital clock device using this new electrode system is shown in Fig. 9. In this case, the connection is the X type, the digit height is 0.8 in., the applied voltage and frequency are 30 Vp-p and 300 Hz, respectively, and L is 100 um. The macroscopic color is light green. The constrast is high enough and viewing angle is sufficiently wide. The haze around some figures is apparently due to misalignment of liquid crystal molecules.

CONCLUSION

Some characteristics of the new liquid crystal cell with crossed interdigital electrodes have been described. It has some advantages compared with a conventional DAP liquid crystal cell. These advantages are as follow:

1. Wider viewing angle;
2. Simpler manufacture of large panels;
3. Lower power consumption because of the smaller area of the electrodes; and
4. Smaller color changes with the applied voltage.

It has been demonstrated that a digital clock device using this electrode system has good quality.

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REFERENCES

1. G.H. Heilmeier, L.A. Zanoni, and L.A. Barton, Proc. IEEE 56, 1162 (1968)
2. M. Schadt and W. Helfrich, Appl. Phys. Letters 18, 127 (1971)
3. A. Boller, H. Scherrer, M. Schadt, and P. Wild, Proc. IEEE 60, 1002 (1972)
4. D. Jones and S. Lu, 1972 SID Symposium Digest of Technical Papers, P 100.
5. S. Kobayashi, 1973 SID Symposium Digest of Technical Papers, P 40.
6. 1972 Catalog ILIXCO Co., Cleveland, Ohio.
7. G. Assouline, M. Hareng, E. Leiba, and M. Roncillant, Electron. Letters 8, 45 (1972)
8. M.F. Schiekel and K. Fahrenschon, 1972 SID Symposium Digest of Technical Papers, P 98.
9. R.A. Soref and M.J. Rafuse, J. Appl. Phys. 43, 2029 (1972).